Rainwater harvesting potential of University of Cape Coast campus: a GIS approach

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This study accesses the potential of rainwater harvesting as an alternative to conventional water supply scheme in University of Cape Coast. The study involves estimating the surface area of rooftops on the University of Cape Coast campus by using Geographical Information System (GIS), obtaining the mean annual rainfall from the meteorological survey department and determining the quantity of rainwater that can be harvested on UCC campus. Satellite imagery of the whole campus is obtained with Google Earth. Thematic Maps are generated for 2008 to 2012. The volume of rainwater is then calculated for each year. From the calculation, it is realized that an average volume of 178,441m^3 of rainwater can be harvested each year. The average water demand of the university during peak seasons is estimated to be 548.1m^3 per day. This implies that, the rainwater can serve the University for about 325 days.

Introduction

Water has been a key to life for people all over the world. It has been a basic need that one cannot do without. The provision of safe drinking water and sanitation facilities are the primary requirement for healthy living in any society. Most societies in the developing countries use water to generate and sustain economic growth. Roughly 780 million people around the world lack access to clean drinking water and an estimated 2.5 million people are without access to safe sanitation facilities (Salaam - Blyther, 2012). Africa has 3,991km^3/yr of renewable fresh water resource, but the continent suffers much from water crisis (Khaka, Malesu, Mati, Odour, & Nyabenge, 2006). In Ghana, though the country is well endowed with water resources compared to other developing countries, the amount of water available changes remarkably from season to season as well as from year to year. The distribution of water within the country is far from uniform with the south western part better watered than the coastal and northern regions (Afful, 2012). The main source of water supply for most cities and towns has been surface water and ground water of which all depends on the rainwater recharge. Conventional water supply system is becoming capital intensive as a result of pollution from human activities such as mining, farming and other industrial activities. Rainwater harvesting has been an old technology used in areas where conventional water supply systems have failed to meet the needs of the people. It is a technology in which rainwater is collected and stored from rooftops, land sources and catchment. It is a simple, affordable and environmentally friendly way of conserving water. Rainwater is perceived to be naturally clean therefore no need for special treatment.

Water scarcity has been one of the major challenges for the University of Cape Coast. The main source of water supply has been the conventional water supply system from the Brimsu head works (GWCL, 2012). The increase in the population of the students has resulted in inadequate quantity of water supplied to the residents. The over reliance on this water supply for various activities including irrigation, car washing, laundry and other water related activities puts pressure on existing demand. This situation has called for the need to look for other ways of providing potable water to residents.

Methodology

Study area

University of cape coast is one of the rare universities in the world which boards the ocean. It lies about 200m from the Atlantic Ocean. It has a geographic bounding coordinate of 1^o 16’ 33”W, 5o 8’ 10”N to North East, 1^o 17’ 51”, W5^o 8’ 10”N to the North West, 1^o 17’ 51”, W5^o5’ 56”N to the South East and 1^o 16’ 33”W, 5^o5’ 56”N to the South West (UCC, 2013). The campus is divided in to the southern campus (old site) Figure 1. which has a higher relief compared with the north campus (new site) Figure 2 which is generally low laying. The university is located within the dry equatorial climatic zone of Ghana. The University of Cape Coast has a student population of 35,922, 14,815 of them being regular while 2,146 are sandwich and the rest are distant learning students, academic staff and a number of supporting staffs (UCC, 2013).

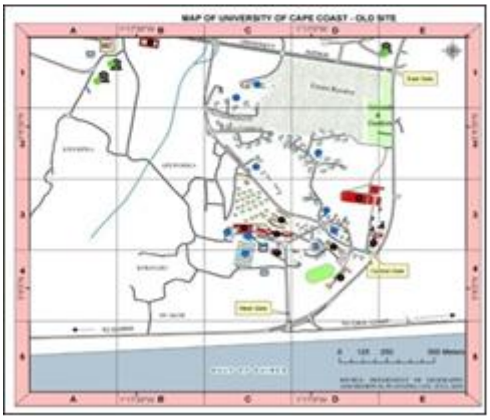

Figure 1. South Campus (old site)

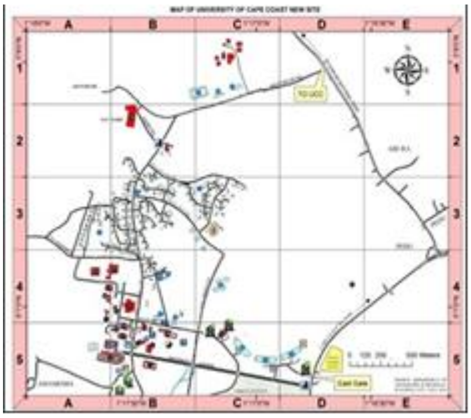

Figure 2. North Campus (new site)

Data collection

In this research all the buildings in the study area was the sample frame. Buildings which are close to campus but not owned and managed by the university was ignored since the research looks at knowing the potential rain to be harvested by the university. The roofs captured were grouped into three main themes, one being accommodation facilities this included hall facilities for students both graduate and undergraduates. It also included accommodation facilities run by departments and residential facilities of lecturers and university staffs which are owned and managed by the university and within the boundaries of the university. Another theme was administration facilities and lecture halls and lastly other facilitating structures such as restaurants, banks, summer hats, supermarkets.

Data capture and sourcing

Data used for the study can be categorized in two folds thus geographic data and non-geographic data. The geographic data for this study was obtained from various sources; Google Earth was first used to capture buildings in the study area grouped into accommodation facilities, administrative structures and lectures, and other service facilities. The outputs which were in Keyhole Markup Language format (KML) was converted into feature classes in ESRI geodatabase formats. Reason for this is limitations Google Earth has with analysis of geographic features so sophisticated ESRI ARCGIS is preferred. This was further updated since Google Earth had 2006 aerial photo of the area at the time of this study. A GeoEye satellite image of 2011 of the study was obtained from the GIS/Remote Sensing Section of the Department of Geography in U.C.C. This image was used to update the buildings where new buildings which have been constructed was captured and also due to its 0.5m resolution building which was not captured well were edited in ARCGIS. Field verification was done for the buildings captured. Rainfall data for 1990 – 2012 was obtained from the Meterological Department station in Cape Coast which is about 2km away from the university.

Data processing

Data captured in Google Earth with its format in KML was converted into feature class in ESRI geodatabase using ARCGIS software. This was done through the data interoperability tool of ARCGIS software, an import function was run by using KML as the input data with the desired output being the geodatabase. Also the coordinate system of the converted data was re-projected into a projected coordinated system Ghana Meter Grid which best fits the area of study and to help in the better analysis of the data. The raster GeoEye image of the study area was already processed through geometric and spectral corrections and also re-projected into the already working coordinate system by the Department of Geography. Capturing of roof-tops was done after the vector and raster were overlayed. Columns were created in the attribute table of the captured vector layers (roof-tops) with the output of computed field calculation which multiplied the area size of the roofs with the run-off coefficient and the mean annual rainfall

Data analysis

Generated potential rain water harvest was analysed in terms of the three main categories of the vector layers captured. Also the lowest and the highest potential rain water harvest was analysed in terms of which category of the features it fell within and the specific function and use of the building. Maps were used to display the results of the potential rain water harvest while tables were used to show the exact values of each of the categories of buildings.

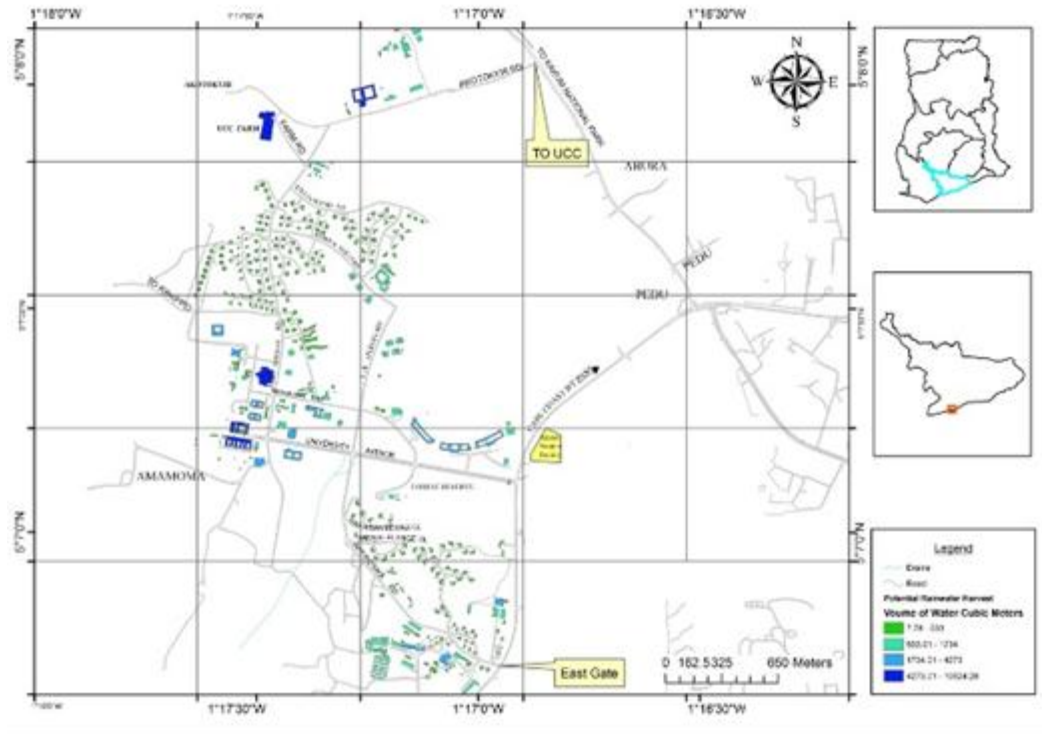

Figure 3. Thematic map of UCC for 2012

Results and discussions

Rainfall data

The rainfall pattern in Cape Coast varies greatly from year to year. There are years with high annual rainfalls while others record very low annual rainfall. With the rainfall data obtained from Meteorological Department Cape Coast which is about 2km from the university. From the data obtained, the year 1990 to 2012, 1998 recorded the least annual rainfall with 417.3 mm having a monthly average of 34.77 mm (Figure

4). The highest rainfall recorded within the span of the data was in 1997 with an amount of 1411.8 mm, having a monthly average of 117.65mm. The mean annual rainfall ranged from 417.3 to 1411.8 with the average value being 919.07mm. Asamoah (1973) had a mean annual rainfall with a range between 900 - 1600mm and the annual mean as 940.1mm. (Owusu-Sekyere, 2011), stated the mean annual rainfall for the study period as 913.6 mm with the annual rainfall ranging from 417.3-1411mm. This shows that the mean annual value dropped from 940.1mm to 913.6mm and increased to 919.07mm. The decrease and increase in the mean can be attributed to climate variability as rainfall patterns are not really predictable. It can be deduced from the comparison that the mean annual rainfall for cape coast revolves around 920 mm.

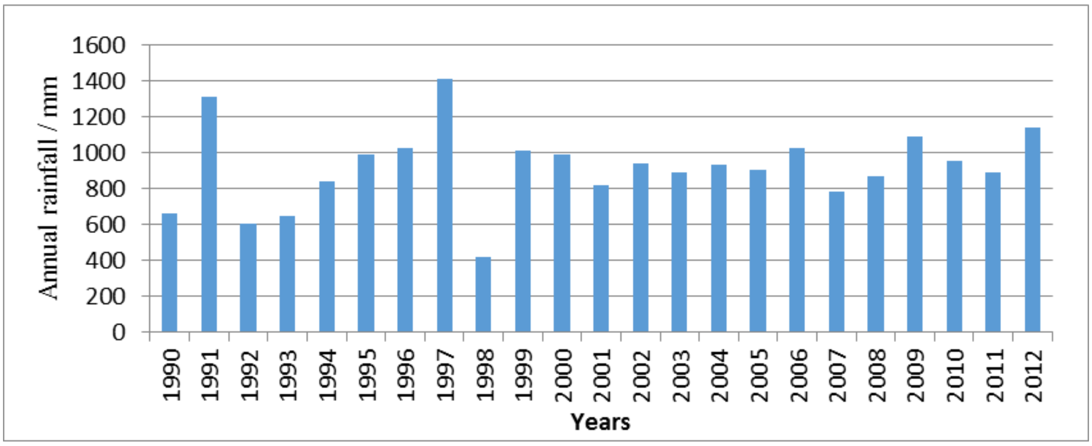

Figure 4. Rainfall pattern of Cape Coast

Source: Meteorological Department Cape Coast

Structures

Due to the infrastructural development on the UCC campus, some structures which were not completed during the year of study were not added to the analysis. The total number of structures digitized within the study area was 597. Out of the 597 structures, 180 of them consisted of administration and other supporting structures such as summer hut, banks and eatery places. The remaining 417 consisted of all the accommodation facilities on campus ranging from residential facilities for lecturers and administrative staffs, halls for students and lodges. Structures categorized under administration facilities on campus have minimum roof area of 17.91m^2, a maximum 10,857.16m^2 and a mean of 635.79m^2. The minimum roof area for the accommodation facilities was 8.03m^2 maximum of 6,462.8m^2 with a mean of 273.32m^2. The total area for residential facilities was 113,974.42m^2 while administration structures were 114,442.86m^2.

The minimum rainfall that the minimum roof area can harvest is 6.27m^3 while the maximum is 8481.72m^3. The total quantity that can be generated with the mean rainfall is 178,441.75m^3. In 2006 Human Development Report by United Nations Development Programme, estimated that the average person in Ghana use about 37 liters of water which translate into 0.037m^3 per day (WSMP, 2009). In a university community with about 14,815 regular students the university needs about 548.15m^3 of water on a daily basis. This shows that the quantity of rainfall that can be harvested is viable to sustain the university community for about 325 days. This will be enough to reduce burden on student during the dry season when water becomes a problem. Academic staff will also have the benefit of this since the average roof area of their houses is 157.4m^2 which can generate 122.96m^3 of water a year. Figure 5 shows the average monthly rainfall data from 1990 to 2012. From the chart, it can be seen that July has the highest recorded rainfall. The weather in Ghana is tropical with the highest rainfall recorded between May and September. The remaining months are normally referred to as dry season. From the chart, it can be seen that throughout the year there is considerable volume of water that can be harvested. From the chart, it can also be seen that the maximum quantity of rainwater that can be harvested will occur in July with an average of 177mm of rainfall which will generate about 40,429m^3 for the month of July. This volume of rainwater is therefore the highest that can be harvested throughout the entire year. Using the maximum rainfall volume harvested as the basis, and assuming this maximum rainfall can occur in day, then the average storage facility that will be required will be 1m^3 per every 5m^2 of roof surface. Considering the variability in pattern of the rainfall an average rainfall of 917mm can be recorded in a year. This implies that about 209,504m^3 of rainwater can be harvested annually. Considering the rate of development on the University of Cape Coast campus, it is evident that the surface area of the roofs will increase and this can lead to more rainwater being harvested in the future.

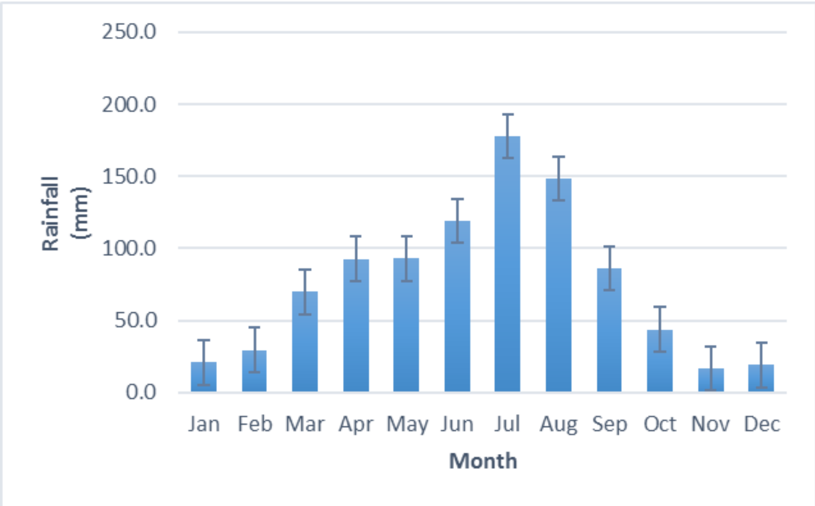

Figure 5. Monthly Average rainfall (1990 – 2012)

Conclusion

From the analysis conducted, it is evident that adopting rainwater harvesting in the university will relieve the university community from the annual ritual of water scarcity. It can also save the university on the amount of money it spends every year to meet its water demands. This therefore concludes that, the university has a very high potential of harvesting rainwater once the necessary infrastructure has been put in place. This can also be extended to other academic institutions within the central region that also have problems of water shortages. This approach can also be used as feasibility study for communities or areas where rainwater harvesting is being considered as an alternative.

Acknowledgements

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